MYCOTAXON

ISSN (print) 0093-4666 (online) 2154-8889 Mycotaxon, Ltd. ©2022

October–December 2022—Volume 137(4), pp. 701–713

https://doi.org/10.5248/137.701 online publication date: 12 September 2023

Four species of *Rhizocarpon* subg. *Phaeothallus* in China

Yan-xue Bi[1], Yan-meng Zhang[1], Zun-tian Zhao[2*], Ling Hu[1*]

[1] *Institute of Environment and Ecology, Shandong Normal University, Jinan, 250014, P. R. China*

[2] *Key Laboratory of Plant Stress Research, College of Life Sciences, Shandong Normal University, Jinan, 250014, P. R. China*

[*]Correspondence to: *Hu_Ling_123@163.com, ztzhao@sdnu.edu.cn*

Abstract—Three lichen species are reported from China for the first time: *Rhizocarpon cinereovirens*, *R. rittokense*, and *R. roridulum*. A revision of the Chinese material determined as *R. infernulum* f. *infernulum* shows that it belongs to *R. infernulum* f. *sylvaticum*. The morphology, secondary chemistry, ecology, and distribution ranges of the species are investigated and discussed. An identification key is given to the species of *Rhizocarpon* subg. *Phaeothallus* in China.

Key words—*Rhizocarpaceae, Rhizocarpales,* saxicolous, taxonomy

Introduction

Rhizocarpon (*Rhizocarpaceae*) was validated by De Candolle in 1805 (Kirk & al. 2008). It is widely distributed on rocks or occurs as parasite on other lichens throughout the world, especially in alpine and polar regions (Matwiejuk 2008). *Rhizocarpon* is characterized by having crustose thallus, usually distinct black prothallus, lecideine apothecia, richly branched and anastomosing paraphyses, *Rhizocarpon*-type and (1–)8-spored asci and hyaline to brown or olive-green, halonate, ellipsoid ascospores that can be transversely septate or submuriform to densely muriform (Feuerer & Timdal 2004, Fletcher & al. 2009, McCarthy & Elix 2014). Thomson (1967) divided the genus *Rhizocarpon* into taxa with a yellow thallus containing rhizocarpic acid (*R.* subg. *Rhizocarpon*) and taxa with

non-yellow (white, ashy, or brown) thallus lacking rhizocarpic acid (*R.* subg. *Phaeothallus*).

Rhizocarpon includes about 235 species worldwide (Lücking & al. 2016; Davydov & Yakovchenko 2017; Etayo 2017; Kalb & Aptroot 2017; Paukov & al. 2017; Kondratyuk & al. 2018; Fryday 2019; Elix & McCarthy 2019; McCarthy & al. 2020; Spribille & al. 2020), of which 47 have been reported from China (Wei 1991, 2020; Abbas & Wu 1998; Aptroot 2002; Aptroot & Sparrius 2003; Sérusiaux & al. 2003; Golubkov & Maywiejuk 2009; Li & al. 2013; Zhao & al. 2013; Mahire & al. 2015; Wang & al. 2015a,b,c, 2016; Gulina & Anwar 2019; Hu & al. 2020).

During our study of *Rhizocarpon* in China, three additional species have been found: *R. cinereovirens*, *R. rittokense,* and *R. roridulum*; a revision of the Chinese material determined as *R. infernulum* f. *infernulum* showed that it belongs to *R. infernulum* f. *sylvaticum*. An identification key is provided for the 31 species of *Rhizocarpon* subg. *Phaeothallus* known from China.

Materials & methods

The examined specimens are preserved in the Lichen Section of Botanical Herbarium, Shandong Normal University, Jinan, China (SDNU) and the Sectio Lichenum of Herbarium Mycologici Academiae Sinicae, Chinese Academy of Sciences, Beijing, China (HMAS-L). Macromorphological characters were examined under a stereomicroscope (COIC XTL7045B2) and micromorphological characters under a polarizing microscope (Olympus CX41). For identification, the thallus and medulla were tested with K (a 10% aqueous solution of potassium hydroxide), C (a solution of aqueous sodium hypochlorite), I (Lugol's iodine), N (a 50% aqueous solution of nitric acid), and P (a saturated solution of p-phenylenediamine in 95% ethyl alcohol). Lichen substances were identified using standardized thin-layer chromatography techniques (TLC) with solvent system C (Orange & al. 2010). Photographs were taken with an Olympus SZX16 and a BX61 microscope with a DP72 lens.

Taxonomy

Rhizocarpon cinereovirens (Müll. Arg.) Vain., Acta Soc. Fauna Fl. Fenn. 53(1): 336 (1922) Fig. 1

Thallus crustose, cream-colored to pale brown, areolate to bullate, 2–5 cm diam.; areoles rounded to angular, flat to convex, smooth, continuous, 0.2–0.4 mm diam. Prothallus absent. Medulla I–. Apothecia lecideine, black, sessile to somewhat immersed, 0.3–0.6 mm diam., rounded to angular,

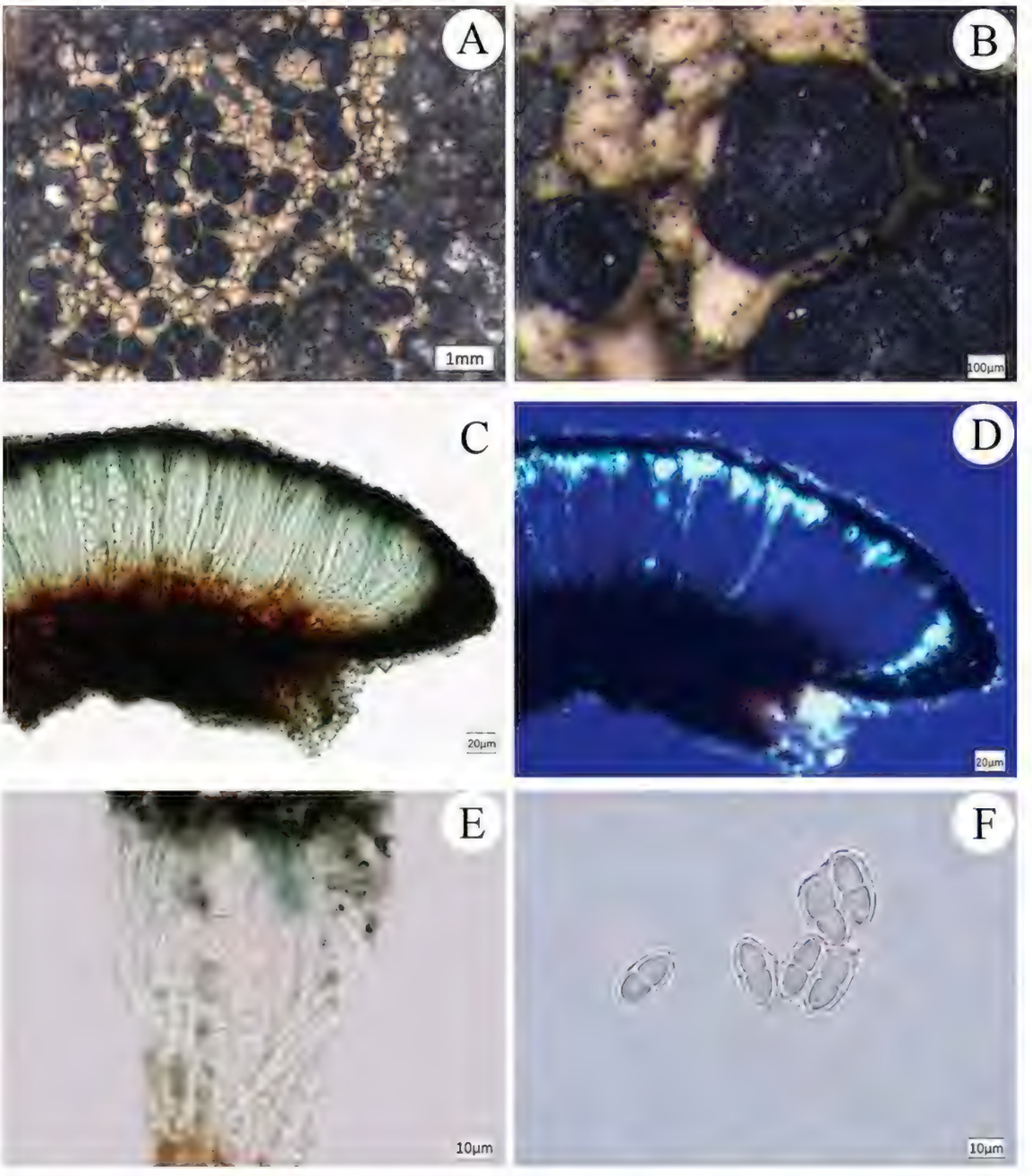

Fig. 1. *Rhizocarpon cinereovirens* (HMAS-L–Gao114944). A. Thallus; B. Apothecia; C. Apothecium section; D. Crystals in exciple and epihymenium; E. Ascus; F. Ascospores. Scale bars: A = 1 mm; B = 100 μm; C, D = 20 μm; E, F = 10 μm.

flat to weakly convex; margin thin, epruinose. Exciple dark brown, K–, with crystals dissolving in K; epihymenium dark green, K+ green, with crystals dissolving in K; hymenium hyaline; paraphyses branched and anastomosing, scarcely swelling at apex, with a green-blue cap; hypothecium dark brown. Asci 8-spored. Ascospores hyaline, 1-septate, 15–17 × 6.5–8.5 μm, halonate. Conidiomata not seen.

Chemistry—Medulla K+ yellow turning red, C–, P+ yellow. Norstictic acid and stictic acid detected by TLC.

Specimen examined: **CHINA. Jilin, Shulan City**, Qingsong forestry station, alt. 600 m, on siliceous rock, 8 Oct. 1984, Xiangqun Gao 114944 (HMAS-L).

Distribution—Norway, Denmark, Great Britain, Finland, Sweden, Switzerland, Canada, USA (Thomson 1967, Fryday 2002). New to China and to Asia.

Comments—Our specimen conforms to previously published descriptions (Fryday 2002, Fletcher & al. 2009). *Rhizocarpon cinereovirens* is characterized by the cream-colored to pale brown thallus, dark green epihymenium with crystals, hyaline, 1-septate ascospores and by containing norstictic and stictic acid. *Rhizocarpon cinereovirens* is somewhat similar to *R. discoense* Lynge by paraphyses with greenish cap at apex and hyaline 1-septate ascospores, but *R. discoense* has a well-developed exciple with a violet pigmentation (K+ violet), a thallus with grey bullate areoles, and wider ascospores 16–17 × 9–10 µm (Fryday 2002, Fletcher & al. 2009). *Rhizocarpon cinereovirens* is also similar to *R. infernulum* (Nyl.) Lynge f. *infernulum*, which has a more well-developed exciple with a hyaline interior, and less richly branched and anastomosing paraphyses with more sharply defined caps that are brown rather than green. In additon, the lichen substances of *R. infernulum* f. *infernulum* are ± stictic acid (Fryday 2002, Fletcher & al. 2009).

Rhizocarpon rittokense (Hellb.) Th. Fr., Lichenogr. Scand. 2: 615 (1874) Fig. 2

Thallus crustose, brown, areolate to subsquamulose, 3–4 cm diam.; areoles peltate, concave, shining, smooth, scattered, often with pruinose margin, 0.2–1 mm diam. Prothallus present, black. Medulla I–. Apothecia lecideine, black, immersed, 0.2–0.5 mm diam., rounded, flat; margin thin, epruinose. Exciple dark brown, K+ violet, with crystals dissolved in K; epihymenium brown, K+ violet, with crystals dissolved in K; hymenium hyaline; paraphyses branched and anastomosing, with a sharply delimited, brown-pigmented cap; hypothecium dark brown. Asci 8-spored. Ascospores brown-green to dark brown, 1-septate, 18–23 × 11.5–15 µm, halonate. Conidiomata not seen.

Chemistry—Medulla K–, C–, P–. Barbatic acid detected by TLC.

Specimens examined: **CHINA. Sichuan, Luding Co.**, Moxi Town, Yajiagen, alt. 4000 m, 29.9100°N 102.0038°E, on siliceous rock, 13 Oct. 2015, Weicheng Wang, Xiangxiang Zhao, Feixiang Shi, Zuntian Zhao 20150587 (SDNU). **Yunnan, Lijiang City**, Mt. Laojun, alt. 3850 m, on siliceous rock, 25 Aug. 2015, Weicheng Wang 20150513 (SDNU).

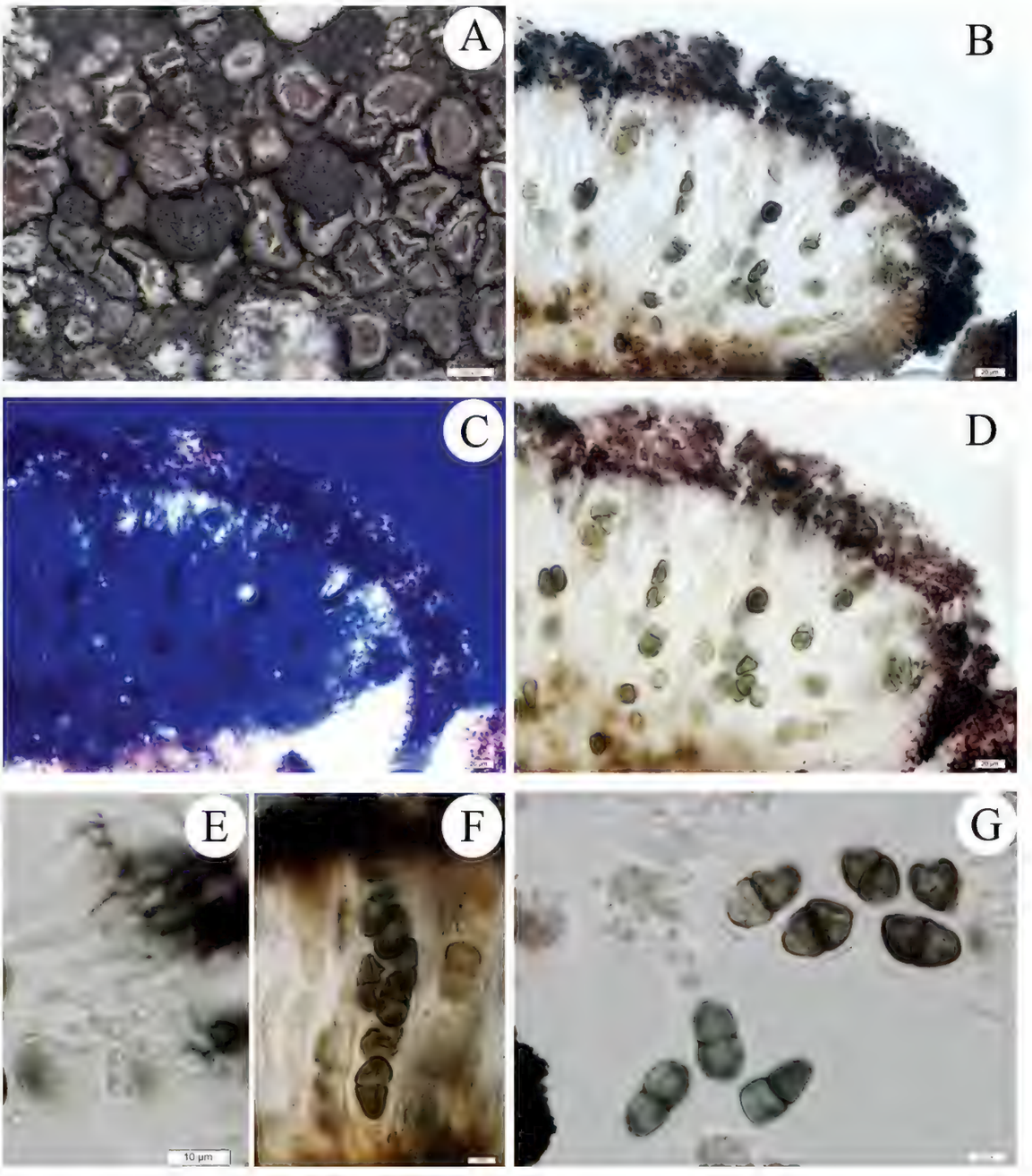

Fig. 2. *Rhizocarpon rittokense* (SDNU–Wang20150587). A. Thallus and apothecia; B. Apothecium section; C. Crystals in exciple and epihymenium; D. K reaction; E. Paraphyses; F. Ascus; G. Ascospores. Scale bars: A = 200 µm; B–D = 20 µm; E–G = 10 µm.

Distribution—Sweden, Denmark, Norway, Iceland, Canada, USA, Russia, Norway (Lynge 1932, Thomson 1967, Timdal & Holtan-Hartwig 1988). New to China.

Comments—Our specimens conform to previously published descriptions, except for the presence of the brown-green ascospores (Thomson 1967).

Rhizocarpon rittokense is characterized by K+ violet exciple with crystals, K+ violet epihymenium with crystals and the subsquamulose thallus. *Rhizocarpon rittokense* is similar in habitat and 1-septate ascospores to *R. groenlandicum* Lynge, which differs by its convex apothecia with a bluish hymenium and its smaller ascospores (17–21 × 10–11 μm; Lynge 1932). *Rhizocarpon rittokense* is also similar to *R. cinereonigrum* Vain. in K+ violet epihymenium and exciple with crystals, but *R. cinereonigrum* differs from *R. rittokense* by K– exciple and larger ascospores (28–38 × 12–l8 μm; Hu & al. 2020).

Rhizocarpon roridulum (Th. Fr.) Malme, Svensk Bot. Tidskr. 8(3): 279, 291 (1914) Fig. 3

Thallus crustose, gray to grayish brown, rimose to areolate, 1.5–2 cm diam.; areoles angular, flat, matt, scattered, 0.2–0.5 mm diam. Prothallus absent. Medulla I–. Apothecia lecideine, black, 0.3–0.5 mm diam., somewhat immersed, rounded to angular, weakly concave; margin thick, epruinose. Exciple dark brown, K+ violet, without crystals; epihymenium brown, K+ violet, without crystals; hymenium hyaline; paraphyses branched and anastomosing, scarcely swelling at apex, without strongly delimited pigmented cap; hypothecium dark brown. Asci 8-spored. Ascospores hyaline, submuriform, with 5–9 cells in optical section, 23–30 × 10.5–15 μm, halonate. Conidiomata not seen.

Chemistry—Medulla K–, C–, P–. No substance detected by TLC.

Specimen examined: **CHINA. Sichuan, Litang Co.**, Mt. Qiazila, alt. 4250 m, on siliceous rock, 16 Oct. 2015, Zuntian Zhao, Feixiang Shi, Xiangxiang Zhao, Weicheng Wang 20150697 (SDNU).

Distribution—Finland, Sweden, Norway (Fries 1874, Ihlen 2004). New to China and to Asia.

Comments—Our specimen conforms to the description of Fries (1874). *Rhizocarpon roridulum* is characterized by the brown to grey-brown thallus, pruinose apothecia (but sometimes the pruina is missing), K+ violet epihymenium, and by not containing lichen substances (Ihlen 2004, Hu & al. 2020). *Rhizocarpon roridulum* is similar to *R. distinctum* Th. Fr. in the dark brown exciple and brown epihymenium, but *R. distinctum* usually has an I+ blue medulla, brown ascospores and contains stictic acid (Fryday 2000). *Rhizocarpon roridulum* is also similar in the K+ violet exciple to *R. geminatum* Körb., which can be distinguished by the 2-spored asci and larger ascospores (36–50 × 17–25 μm; McCarthy & Elix 2014). Additionally, *Rhizocarpon*

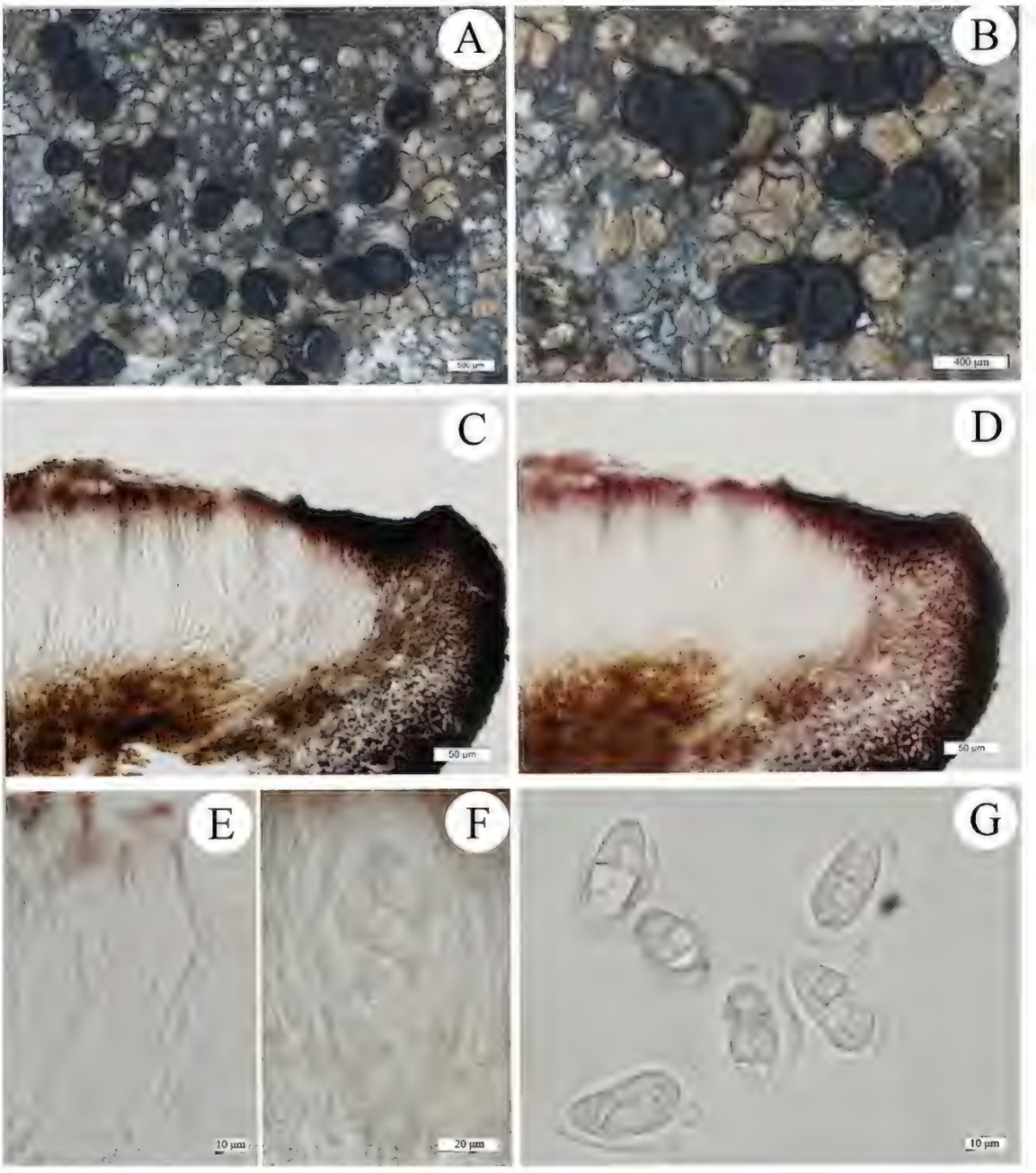

Fig. 3. *Rhizocarpon roridulum* (SDNU–Zhao20150697). A. Thallus; B. Apothecia; C. Apothecium section; D. K reaction; E. Paraphyses; F. Ascus; G. Ascospores. Scale bars: A = 500 µm; B = 400 µm; C, D = 50 µm; E, G = 10 µm; F = 20 µm.

roridulum is similar to *R. amphibium* (Fr.) Körb. in the predominantly reddish brown epihymenium with K+ purple reaction, but *R. amphibium* is characterized by the apothecia never with a white pruina and the exciple in section frequently with a green pigment in the outer and upper part (Ihlen 2004).

Revision

Rhizocarpon infernulum* f. *sylvaticum Fryday, Lichenologist 34(6): 468 (2002)

Thallus crustose, brown, rimose to areolate, areoles rounded to angular, flat to weakly convex, matt, contiguous, 0.5 mm diam. Prothallus absent. Medulla I–. Apothecia lecideine, black, 1 mm diam., sessile to somewhat immersed, rounded to angular, flat to weakly convex; margin thin, persistent, epruinose. Exciple dark brown at the rim, inner part paler brown, K–, without crystals; epihymenium macrocarpa-green, K–, N+ red, without crystals; hymenium hyaline; paraphyses branched and anastomosing, with a sharply delimited, brown-pigmented cap; hypothecium dark brown. Asci 8-spored. Ascospores hyaline, 1-septate, (16–)17.5–20(–24) × 8–10 µm, halonate. Conidiomata not seen.

Chemistry—Medulla K–, C–, P–. No substance detected by TLC.

Specimens examined: **CHINA. Guizhou, Leishan county,** Mt. Leigong, alt. 1800 m, on siliceous rock, 1 Apr. 2011, Yuliang Cheng 20112591A (SDNU); alt. 2100 m, on rock, 1 Apr. 2011, Xingran Kou 20111813 (SDNU); alt. 2700 m, on siliceous rock, 9 Nov. 2009, Lulu Zhang 20103078 (SDNU).

Distribution—Great Britain, Ireland, Sweden, Canada, USA, China (Fryday 2002, Fletcher & al. 2009, Zhao & al. 2013).

Comments—*Rhizocarpon infernulum* f. *sylvaticum* is characterized by the slightly larger spores and a smooth, cracked thallus, compared to the more areolate thallus and smaller spores (15–18 × 7–8.5 µm) of *R. infernulum* f. *infernulum*. Another difference between these two forms is the pigment of epihymenium: Fryday (2002) included the specimens with aeruginose (macrocarpa-green; K–, N+ red) to blue-black epihymenium in f. *infernulum*, and the specimens with invariably hyaline epihymenium in f. *sylvaticum*.

On the contrary, Möller (2021) found that the degree of epihymenium pigments varied within *R. infernulum* f. *sylvaticum*, some specimens had a very thin green epihymenium, and others had a very thick bright green epihymenium. During his investigation of the *R. hochstetteri* group by molecular methods, he found that specimens from clade A2 which he regarded as f. *sylvaticum* form a highly supported clade together with a specimen (11041) that Fryday himself determined as f. *sylvaticum*, and these specimens fit his observations of the type specimen. Moreover, the clade A2 (including f. *sylvaticum*) and A3 (including f. *infernulum*) were well supported and separated. He suggested (Möller 2021)

that f. *sylvatica* should be raised to species rank, but did not publish a formal proposal. Here, we retain the name *R. infernulum* f. *sylvaticum*.

Rhizocarpon infernulum f. *infernulum* was first reported from China by Zhao & al. (2013). Recently we re-examined those specimens (SDNU-20103078, 20111813, 20112591A) and we found that the spores measured (16–)17.5–20(–24) × 8–10 µm, much larger than the 15–18 × 7–8.5 µm published by Zhao & al. (2013). The specimen also had a thin, smooth, brown, cracked thallus, sessile apothecia with a persistent proper margin, so we reidentify the specimen as *R. infernulum* f. *sylvaticum*.

Key to the species of *Rhizocarpon* subg. *Phaeothallus* in China

1. Ascospores l-septate 2
1. Ascospores 3-septate to muriform 13
2. Ascospores remaining hyaline or only finally darkening 3
2. Ascospores soon becoming dark green or brown 7
3. Thallus dark brown, medulla I+ blue ..... *R. polycarpum*
3. Thallus ashy, gray, gray-brown or brown, medulla I– 4
4. Epihymenium and exciple containing crystals dissolved in K ..... ***R. cinereovirens***
4. Epihymenium and exciple not containing crystals 5
5. Thallus containing stictic acid; ascospores 22–27 × 9–12 µm ..... *R. hochstetteri*
5. Thallus containing no lichen substances 6
6. Exciple K+ violet; ascospores 14–17 × 6–9 µm ..... *R. expallescens*
6. Exciple K–, ascospores 17.5–20 × 8–11 µm ..... ***R. infernulum* f. *sylvaticum***
7. Medulla I+ blue, ascospores usually <20 µm long 8
7. Medulla I–, ascospores usually >20 µm long 9
8. Epihymenium brown-black; hymenium hyaline to pale brown, ascospores olive-green or brown, 12.5–16 × 6.5 µm ..... *R. simillimum*
8. Epihymenium black; hymenium hyaline below, upper part pale red, ascospores brown, 12.5–17.5 × 6–7 µm ..... *R. umense*
9. Epihymenium olive-brown to green-black, K–; containing norstictic acid or stictic acid, ascospores blue-green, 18–26 × 8–13 µm ..... *R. copelandii*
9. Epihymenium red-brown to black brown, K+ violet 10
10. Exciple with crystals dissolved in K 11
10. Exciple without crystals 12
11. Exciple K-; ascospores 28–38 × 12–l8 µm ..... *R. cinereonigrum*
11. Exciple K+ violet; ascospores 18–23 × 11.5–15 µm ..... ***R. rittokense***
12. Thallus pale gray-brown to brown, containing no lichen substances; ascospores olive-brown to red-brown or brown, 25–35 × 12–15 µm ..... *R. badioatrum*
12. Thallus gray to dark brown, containing gyrophoric acid; ascospores olive-brown, 35–40 × 10–15 µm ..... *R. sinense*
13. Asci 1- or 2-spored 14

13. Asci 8-spored 17
14. Asci 1-spored 15
14. Asci 2-spored 16
15. Ascospores green-brown to dark-brown ..... *R.disporum*
15. Ascospores dark-green ..... *R.solitarium*
16. Thallus gray, pruinose, containing norstictic acid and stictic acid; epihymenium with crystals dissolved in K; ascospores dark green, 35–65 × 15–30 μm ..... *R. geminatum*
16. Thallus dark grey, epruinose, containing barbatic acid; epihymenium without crystals; ascospores hyaline, 37–55 × 20–25 μm ..... *R. subgeminatum*
17. Ascospores submuriform, with 6–10 cells in optical section 18
17. Ascospores muriform 23
18. Thallus leprose ..... *R. leprosulum*
18. Thallus areolate 19
19. Thallus containing stictic acid 20
19. Thallus containing no lichen substances 21
20. Medulla I+ blue, ascospores soon brown, 3-septate to submuriform, 20–27.5 × 7.5–12.5 μm ..... *R. distinctum*
20. Medulla I-, ascospores persistently hyaline, submuriform, 25–30 × 15–18 μm ..... *R. umbilicatum*
21. Prothallus distinct, black; ascospores dark green, submuriform, 20–25 × 12 μm ..... *R. intersitum*
21. Prothallus absent or indistinct; ascospores hyaline 22
22. Hymenium vertically streaked red-brown, K+ violet; ascospores hyaline, pale brown-green when over mature, 15–22.5 × 7.5–12.5 μm ..... *R. subpostumum*
22. Hymenium hyaline, K–; ascospores persistently hyaline, 23–30 × 10.5–15 μm ..... ***R. roridulum***
23. Thallus ochraceous or rusty, epihymenium dark olive-brown, ascospores hyaline, 24–34 × 14–16 μm ..... *R. ischnothallum*
23. Thallus white, grey, brown 24
24. Ascospores <20 μm long (17–19 × 7–9 μm), hyaline, pale-brown when over mature ..... *R. cinereocaesium*
24. Ascospores >20 μm long 25
25. Ascospores soon becoming brown, 25–40 × 10–16 μm ..... *R. grande*
25. Ascospores remaining hyaline or only finally darkening 26
26. Ascospores persistently hyaline 27
26. Ascospores hyaline, pale-brown when over mature 29
27. Thallus containing stictic acid ..... *R. reductum*
27. Thallus containing no lichen substances 28
28. Epihymenium bluish green, K+ brighter; ascospores 25–35 × 12.5–15 μm ..... *R. sublavatum*
28. Epihymenium pale brown, or brown and olive-green intermixed, K–; ascospores 31–40 × 12.5–13.5 μm ..... *R. lavatum*

29. Medulla K–; ascospores 28–34 × 12–15 µm ..... *R. gracile*
29. Medulla K+ yellow or red 30
30. Medulla K+ yellow, containing stictic acid ..... *R. petraeum*
30. Medulla K+ red, containing norstictic acid ..... *R. rubescens*

Acknowledgements

We thank Dr. Einar Timdal (Natural History Museum, University of Oslo, Norway) and Dr. Shou-Yu Guo (State Key Laboratory of Mycology, Institute of Microbiology, Chinese Academy of Sciences, Beijing, China) for guidance in pre-submission review. We also thank Dr. Einar Timdal and Dr. Alan Fryday (Department of Plant Biology, Michigan State University, USA) for specimen identification and helpful suggestions during our research. This study was supported by the Emergency management project of National Natural Science Foundation of China (31750001), the National Natural Science Foundation of China (31900010).

Literature cited

Abbas A, Wu JN. 1998. Lichens of Xinjiang. Sci-Tech & Hygiene Publishing House of Xinjiang (K), Urumqi. 178 p.

Aptroot A. 2002. Corticolous and saxicolous lichens from Xishuangbanna, southern Yunnan, China.

Aptroot A, Sparrius LB. 2003. New microlichens from Taiwan. Fungal Diversity 14: 1–50.

Davydov EA, Yakovchenko LS. 2017. *Rhizocarpon smaragdulum*, a new monosporic yellow-thalline species and some additional species of the genus *Rhizocarpon* from the Altai Mountains (Siberia). Lichenologist 49(5): 457–466. https://doi.org/10.1017/S0024282917000469

Elix JA, McCarthy PM. 2019. *Rhizocarpon bicolor* (lichenized *Ascomycota*, *Rhizocarpaceae*), a new species from south-eastern Australia. Australasian Lichenology 85: 51.

Etayo J. 2017. Lichenicolous fungi of Ecuador [Hongos liquenícolas de Ecuador]. Opera Lilloana 50. 535 p.

Feuerer T, Timdal E. 2004. *Rhizocarpon*. 456–466, in: TH Nash & al. (eds). Lichen flora of the greater Sonoran desert region, vol. 2. Tempe AZ, Lichens Unlimited, Arizona State University.

Fletcher A, Gilbert OL, Clayden S, Fryday AM. 2009. *Rhizocarpon* Ramond ex DC. (1805). 792–808, in: CW Smith & al. (eds). Lichens of Great Britain and Ireland. British Lichen Society, London.

Fries TM. 1874. Lichenographia scandinavica. Pars secunda: 325–639.

Fryday AM. 2000. On *Rhizocarpon obscuratum* (Ach.) Massal., with notes on some related species in the British Isles. Lichenologist 32(3): 207–224. https://doi.org/10.1006/lich.2000.0269

Fryday AM. 2002. A revision of the species of the *Rhizocarpon hochstetteri* group occurring in the British Isles. Lichenologist 34(6): 451–477. http://dx.doi.org/10.1006/lich.2002.0416

Fryday AM. 2019. Eleven new species of crustose lichenized fungi from the Falkland Islands (Islas Malvinas). Lichenologist 51(3): 235–267. https://doi.org/10.1017/S0024282919000185

Golubkov VV, Matwiejuk A. 2009. Some new records of *Rhizocarpon* from North-Eastern Poland and North-Western Belarus. Acta Mycologica 44(2): 201–210. https://doi.org/10.5586/am.2009.018

Gulina H, Anwar T. 2019. Taxonomic study on *Rhizocarpon* in Xinjiang, China. Acta Botanica Boreali-Occidentalia Sinica 39(9): 1589–1599. https://doi.org/10.7606/j.issn.1000-4025.2019.09.1589

Hu L, Zhang X, Wang CX, Zhao ZT. 2020. Four non-yellow species of *Rhizocarpon* new to China. Mycotaxon 135: 883–891. https://doi.org/10.5248/135.883

Ihlen PG. 2004. Taxonomy of the non-yellow species of *Rhizocarpon* (*Rhizocarpaceae*, lichenized *Ascomycota*) in the Nordic countries, with hyaline and muriform ascospores. Mycological Research 108: 533–570. https://doi.org/10.1017/S0953756204009803

Kalb K, Aptroot A. 2017. Lichenes neotropici fascikel XVI. Archive for Lichenology 12. 12 p.

Kirk PM, Cannon PF, Minter DW, Stalpers JA. 2008. Ainsworth & Bisby's dictionary of the fungi, 10th ed. CAB International, Wallingford. 771 p. https://doi.org/10.1079/9780851998268.0000

Kondratyuk SY, Lökös L, Halda JP, Farkas E, Upreti DK, Thell A, Woo JJ, Oh SO, Hur JS. 2018. New and noteworthy lichen-forming and lichenicolous fungi 7. Acta Botanica Hungarica 60(1–2): 115–184. https://doi.org/10.1556/034.60.2018.1-2.8

Li X, Li C, Wang HY. 2013. Two species of *Rhizocarpon* new to China. Modern Agricultural Science and Technology 6: 146–147.

Lücking R, Hodkinson BP, Leavitt SD. 2016. The 2016 classification of lichenized fungi in the *Ascomycota* and *Basidiomycota*: approaching one thousand genera. Bryologist 119(4): 361–416. https://doi.org/10.1639/0007-2745-119.4.361

Lynge B. 1932. A revision of the genus *Rhizocarpon* (Ram.) Th. Fr. in Greenland. Skrifter om Svalbard og Ishavet 47: 1–30.

Mahire N, Tursungul R, Wen XM, Abdulla A, Reyim M. 2015. A preliminary study on the lichen genus *Rhizocarpon* Ramond ex DC. in Xinjiang, China. Acta Botanica Boreali-Occidentalia Sinica 35(2): 422–426. https://doi.org/10.7606/j.issn.1000-4025.2015.02.0422

Matwiejuk A. 2008. Noteworthy species of the genus *Rhizocarpon* Ramond ex DC. (*Rhizocarpaceae*, lichenized *Ascomycota*) in the LBL herbarium. Annales UMCS, Biologia 63(1): 79–92. http://doi.org/10.2478/v10067-008-0006-1

McCarthy PM, Elix JA. 2014. The lichen genus *Rhizocarpon* in mainland Australia. Telopea 16: 195–211. https://doi.org/10.7751/telopea20148124

McCarthy PM, Elix JA, Kantvilas G. 2020. New species and new records of the lichen genus *Rhizocarpon* from Tasmania with a key to the Australian taxa. Australasian Lichenology 86: 36–61.

Möller EJ. 2021. Molecular phylogenetics and genus delimitation in the *Rhizocarpaceae* (lichenized ascomycetes) with focus on the *Rhizocarpon hochstetteri*-complex. Masters Thesis, Faculty of Mathematics and Natural Sciences, University of Oslo. https://www.duo.uio.no/bitstream/handle/10852/89898/11/ErikMoller_thesis_fixed3.pdf

Orange A, James PW, White FJ. 2010. Microchemical methods for the identification of lichens. 2nd edition. London, British Lichen Society.

Paukov A, Sipman HJM, Kukwa M, Repin R, Teptina A. 2017. New lichen records from the mountains Kinabalu and Tambuyukon (Kinabalu Park, Malaysian Borneo). Herzogia 30(1): 237–252. https://doi.org/10.13158/heia.30.1.2017.237

Sérusiaux E, Diederich P, Ertz D, van den Boom P. 2003. New or interesting lichens and lichenicolous fungi from Belgium, Luxembourg and Northern France. IX. Lejeunia 173: 1–48.

Spribille T, Fryday AM, Pérez-Ortega S, Svensson M, Tønsberg T, Ekman S, Holien H & al. 2020. Lichens and associated fungi from Glacier Bay National Park Alaska. The Lichenologist 52(2): 61–181. https://doi.org/10.1017/S0024282920000079

Thomson JW. 1967. Notes on *Rhizocarpon* in the Arctic. Nova Hedwigia 14: 421–481.

Timdal E, Holtan-Hartwig J. 1988. A preliminary key to *Rhizocarpon* in Scandinavia. Graphis Scripta 2: 41–54.

Wang WC, Zhao ZT. 2015a. Four new records of *Rhizocarpon* from China. Mycotaxon 130: 739–747. https://doi.org/10.5248/130.739

Wang WC, Zhao ZT. 2015b. Four *Rhizocarpon* species new to China. Mycotaxon 130: 883–891. https://doi.org/10.5248/130.883

Wang WC, Zhao ZT. 2015c. Three new records of *Rhizocarpon* from China. Acta Botanica Boreali-Occidentalia Sinica 35(8): 1694–1696. https://doi.org/10.7606/j.issn.1000-4025.2015.08.1694

Wang WC, Ren ZJ, Zhang LL. 2016. New records of *Rhizocarpon* from Hengduan Mountains, China. Mycotaxon 131: 589–596. https://doi.org/10.5248/131.589

Wei JC. 1991. An enumeration of lichens in China. International Academic Publishers, Beijing.

Wei JC. 2020. The enumeration of lichenized fungi in China. China Forestry Publishing House, Beijing.

Zhao ZT, Li C, Zhao X, Zhang LL. 2013. New records of *Rhizocarpon* from China. Mycotaxon 125: 217–226. https://doi.org/10.5248/125.217